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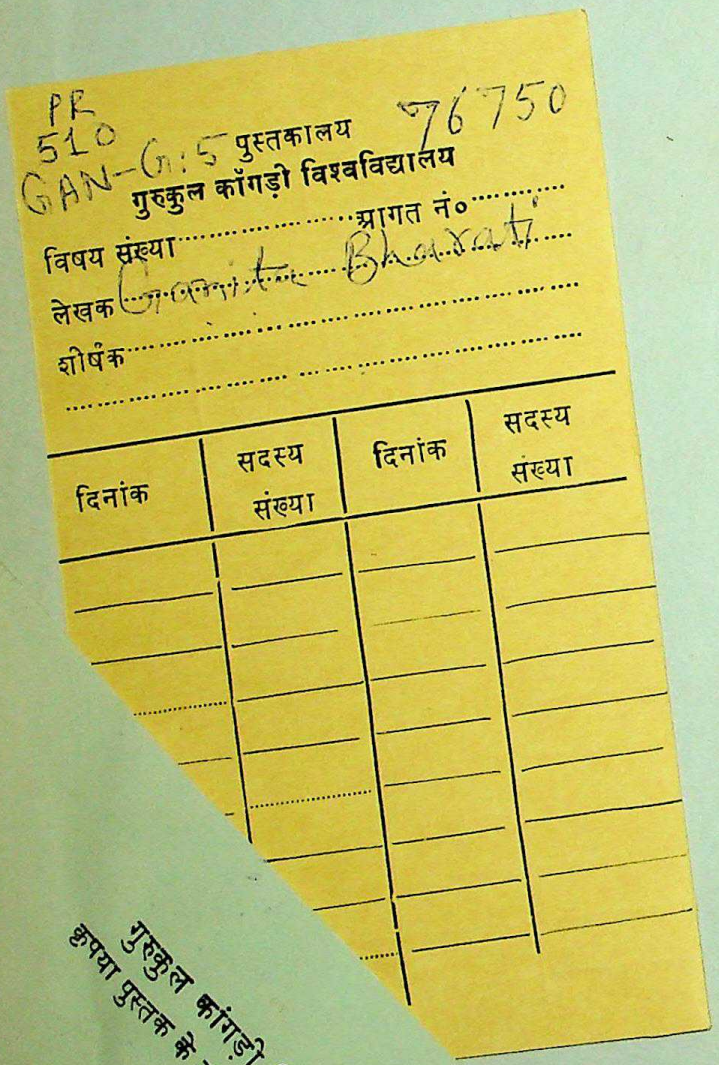

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गणित-भारती
Ganita-Bharati

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Ganita-Bharati
BULL. IND. SOC. HIST. MATH.

With Roots towards Āryabhaṭa's π-value

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1. INTRODUCTION

Numerical results which have been transmitted without a proof necessarily induce historians of mathematics to look for a way in which, using methods and theories known in the period concerned, the same results can be obtained. A succcessful explication is, however, never without the very documents remaining from the ancient authors guaranteed correct. We wish to show this by an example, that of the computation of n-th roots.

The n-th root of a number A is defined by $x^n = A$, from which we can derive $x^{n+1} = Ax$, and "just playing around" by additions and subtractions, one can see that also holds true

$$(n-1)x^{n+1} + (n+1)Ax = (n+1)x^{n+1} + (n-1)Ax$$

or

$$x = \frac{(n+1)A + (n-1)x^n}{(n-1)A + (n+1)x^n} \cdot x$$

Now do not divide the factor x at both sides, but go over to an iterative process

$$x_{i+1} = \frac{(n+1)A + (n-1)x_i^n}{(n-1)A + (n+1)x_i^n} \cdot x_i$$

and one arrives at a computation of the n-th root, if the iteration leads to convergence, and if one computes the error in x_i at the final step.

Let us first simply "try" for the roots of 2.

$n = 2$, $(6 + x^2)x/(2 + 3x^2)$
1, 1.4, 1.414213198, 1.414213563;

$n = 3$, $(4 + x^3)x/(2 + 2x^3)$
1, 1.25, 1.259920635, 1.259921050;

$n = 5$, $(6 + 2x^5)x/(4 + 3x^5)$
1, 1.142857143, 1.148698050, 1.148698056.

We just computed the third iteration-value at nine digits and arrived at values exact to the ninth digit at least.

We remark that one can obtain rational values putting $x = a/b$ in the general formulas.

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One can easily compute the error for $n = 2$ and $n = 3$, just computing the values of $A - x^2$ and $A - x^3$ . . . . The results are

$$n = 2, \quad (A - x^2)^3/(A + 3x^2)^2$$
$$n = 3, \quad (A - x^3)^3(A + x^3)/(A + 2x^3)^3$$

We have in this way already demonstrated that for square and cubic roots the processes do converge if $|A - x^n| < 1$, and as we derived the value of D in $A = x^n + D$, in these cases, by using the binomial theorem one can easily compute corrections on the value obtained. Thus e.g. for the square roots from

$$A = x^2 + D, \quad \sqrt{A} = x + \tfrac{1}{2} \cdot D/x - D^2/8x^3 + \ldots$$

For the general integral value of n we find in the same way from

$$A[(n-1)A + (n+1)x^n]^n - [(n+1)A + (n-1)x^n]^n \cdot x^n$$

differentiating this $F(A)$ and substituting $A - x^n$ that

$$F(x^n) = F'(x^n) = F''(x^n) = 0$$

whereas the third derivative is different from zero. This means that $F(A) = (A - x^n)^3 \cdot G(A)$, in which $G(A)$ is a polynomial in A. Thus under the analogous condition $|A - x^n| < 1$ there is convergence and at each step the number of exact digits is more than three times enlarged.

The historical way was different. Edmund Halley[1], not yet having at his disposal a current index n derived for $n = 2, 3, 4, 5, 6, 7 \ldots$ the numerical coefficients, using the Taylor series till the third term for

$$A = (a + x)^n = a^n + na^{n-1}x + \tfrac{1}{2}n(n-1)a^{n-2}x^2$$

and determining an approximate value of the root for this quadratic equation.

Heron's method for cubic roots, as given in *Metrica* III, 20, is numerically equivalent to Halley's relations.

There is still another problem, which we like to indicate beforehand. This problem—as appears to the present author[2]—destroyed the perfect method for the computation of a table of sines by the ancient Indian mathematicians. Their method consisted not in an "average" or an "interpolation" . . . but by a correct formula computing the values of sin *na* whenever sin *a* is known. The poor result, in the extant tables is due to a too great error in the basic value, and this is then caused by a "minus-sign", which destroyed the accuracy of the basic value as subtraction of two nearly equal quantities did occur.

Al-Kāshī[3] recognised this difficulty in his computation of π and he made clear that the minus sign appearing in the last step of the computation

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made him lose the accuracy, the first half of his eighteen place values cancelling.

2. On the π of Āryabhaṭa I

Under this title *a* study of Afzal Ahmad[4] in this journal appeared, an attempt to derive Āryabhaṭa's value

$$62832/20000 = 31416/10000 = (3927/1250).$$

Rightly Afzal Ahmad avoided the interpretation which lies very near at hand: "We know the more accurate value of π, namely 3.141592 . . . and this rounded off to the fourth decimal is 3.1416."

By considering the 128-gon, inscribed into a circle the perimeter can be computed by doubling the side-number, and Afzal Ahmad seems to have been a victim of the "minus-sign" occurring at the last step of his procedure, consisting in doubling the number of sides, starting with the inscribed square. This leads to the procedure

"+2, square root"

iterated, followed by the difference of the last result and 2, then again a square root.

Computing at nine digits exact one has to find

1.414213562

1.847759065

1.961570561

1.990369453

1.997590912

1.999397637

and one can easily verify that Afzal Ahmad took all but the last two values rounded off at a unit too much in the last digit . . . which does *not* disturb the final result in *this* series. But then we have to take

$$2 - 1.999397637 = 0.000602363$$

of which the square root is 0.024543085 . . . which multiplied into 128 yields 3.141514 . . . and this should be rounded off to 3.1415 . . . which just causes to lose "the 6 one is looking for".

Indeed, the minus sign with Afzal Ahmad values yields a difference 0.0006024. Losing many digits in the difference only three are left as exact. The square root gives then 0.024543838, corresponding to the value 0.0245438, which multiplied into 128 yields 3.1416064 . . . which then would result in the rounded off value 3.1416,

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We can, however,—though it is clear that the wished result cannot be obtained from the doubling of the number of sides—remark that Heron, *Metrica*, I, 18, shows by an "exhaustive method" similar to that of Archimedes in his *Squaring of the Parabola*, that a segment of a circle is greater than four-thirds of the isosceles triangle inscribed in the segment, same basis, same vertex.

Chr. Huygens[5] rediscovered Heron's theorem, completed it also for the "circumscribed triangle", deriving a factor 2/3 as being too great, and devised a still better approximation in his *De circuli magnitudine inventa*. As stands to reason Huygens' proofs are related in the history of mathematics, just as he did it. Somewhat different, but straightforward, we derive the results here too.

1. If AC and BC are tangents to the segment of the circle ATB, then BT is bisectrix of the angle ABC and therefore $CT > GT$ and thus the area of the triangle CDE is greater than 1/4 of the triangle ABC. The ratio of the areas of the triangles TEB and TGB, having in common the side TB and an angle equal is as $EB : GB$. Because of the inequality of the triangle we evidently have

$$EB > TB/2 > AB/4$$

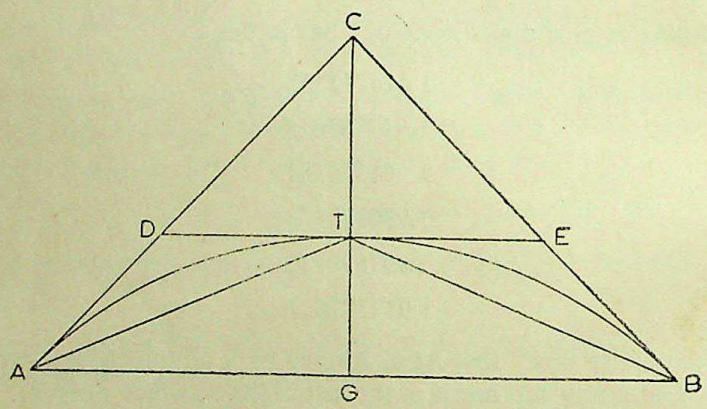

FIG. 1

The area of the triangles ADT and TEB together is therefore greater than a quarter of the area TAB, which means that repeating the cutting away of triangles by means of tangents at the midpoints of the arcs every time more than a quarter of the triangles is cut away . . . and in the limit one-third of ATB is cut away more than CDE, which is greater than ATB. Thus far the segment remains less than two-thirds of ABC.

II. A circle ACB, compared with a parabola, passing through A, B and touching the circle at C obviously comes inside the parabola below the line

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AB . . . and therefore is above the parabola at the other side of AB. The area of the segment of the circle is therefore greater than that of the segment of the parabola, which is four-thirds of the triangle ABC.

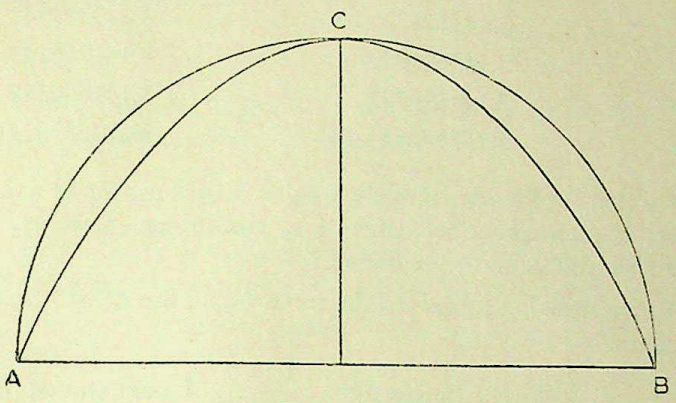

FIG. 2

Denoting half of the central angle for a regular polygon by a we have for the segments ACB in Fig. 1,

$$\text{Triangle } ACB = \tan a \, (\sin a)^2 = (\sin a)^3/\cos a$$

and therefore the segment is smaller than

$$\sin a \cos a + 2(\sin a)^3/3 \cos a,$$

or

$$\sin a \, (2 + \cos a^2)/3 \cos a.$$

For ACB in Fig. 2 follows

$$\sin a \cos a + 4 \sin a(1 - \cos a)/3$$

or

$$\sin a(4 - \cos a)/3.$$

As sin a and tan a are the areas of the central triangles of the inscribed and circumscribed regular polygons, we have correction factors for the area of the segment, obtained from these triangles. First here we collect the values of the segments according to these Heron-Huygens corrections starting with the hexagon, i.e. $a = 30°$, and doubling the number of sides. The procedure of computing the sines is the same as that used by Afzal Ahmed too, but starts with the square root of 3 and applies then the iteration "+2, square root" until the last step. We multiply then into the number of sides

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used for the polygon and the result is

n	Lower Bound for π	Upper Bound for π
6	3.133974597	3.175436482
12	3.141104722	3.143593541
24	3.141561970	3.141716143
48	3.141590732	3.141600348
96	3.141592534	3.141592313

and we see that for 96 sides already a value 3.1416 *cannot* be a final result any more. The circumscribed triangle to the 48-gon, however, gives very precisely 3.141600 as an upper bound.

For comparison we computed the same values for Afzal Ahmad's series of the square

n	Lower Bound for π	Upper Bound for π
4	3.104569500	4.833333333
8	3.139147570	3.151948040
16	3.141437718	3.142221072
32	3.141582936	3.141631656
64	3.141592047	3.141595087
128	3.141592616	3.141592804

In this set we do not find values as near to 3.1416 as it was the case in the series of the hexagon. Moreover, using the method up to the 128-gon an accuracy of seven digits is obtained.

We add that in the *Śulvasūtras* an approximate circulature of the square is to be found, which uses also the factor 1/3. The same procedure for the circulature of the square and the quadrature of the circle is given by Albrecht Dürer, whereas on the back side of the copper plate on which Rembrandt gave his "Prodigal Son", the same drawings are preserved. With so small a number of sides the accuracy cannot be great: it corresponds to the approximation $\pi = 3\frac{1}{8}$.

Finally the continued fraction for Āryabhaṭa's value 3927/1250 is given—with its convergents, in

$$\{3, 7, 16, 11\};\quad 3,\ 22/7,\quad 355/113,\quad 3927/1250$$

The interpolated fractions $(3 + 22k)/(1 + 7k)$ yield for

$k = 1$ 25/8

$k = 15$ 333/106

$k = 16$ 355/113, the convergent itself.

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The continued fraction for π is, with its convergents,

$$\{3, 7, 15, 1, 203, \ldots\}; \quad 3, 22/7, 333/106, 355/113, \ldots$$

the last one being called after the Chinese Tsu Chung Chi ... and after the Dutch mathematician Metius.

ACKNOWLEDGEMENT

The author is thankful to the A. E. van Giffen Institute of the University of Amsterdam for preparing the drawings.

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Ganita-Bharati
BULL. IND. SOC. HIST. MATH

Decimal Denominational Terms in Ancient and Medieval India

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1. INTRODUCTION

Although the choice of ten as a base for numeration is not the best, God favoured it by giving us ten fingers. In India, ten has been the basis for counting since very early days. Later on it served the base for the place-value system of numerals which was invented in India about two thousand years ago. Specific names are found for numbers which are equal in value to 10^n, where $n = 0, 1, 2, \ldots$. Later on these decuple terms were used as names for various notational places when positive integral numbers were written in decimal place-value system.

It is remarkable that Indians developed terminology for denominations upto very high orders in comparison to other ancient nations. In this connection we quote al-Bīrūnī (Vol. I, p. 174) (ca. 1030 A.D.):

> "I have studied the names of the orders of the numbers in various languages with all kinds of people with whom I have been in contact, and have found that no nation goes beyond the thousand. The Arabs too stop with the thousand, which is certainly the most correct and the most natural thing to do. I have written a separate treatise on this subject. Those, however, who go beyond the thousand in their numeral system are the Hindus, ..."

This leads us to ask the following questions: (i) Why was stopping at the thousand considered most correct and natural by al-Bīrūnī? (ii) Was he ignorant of the Greek term *myriad* (from myrioi, "countless") which stood for ten-thousand? Which is his separate treatise on the subject? (iv) What about the terms for large numbers used by Archimedes (died 212 B.C.) in his book entitled *Principles* which dealt with the naming of numbers (Heath, p. xxxvi)? I leave the matter and come to the main topic.

2. DECUPLE TERMS IN VEDIC LITERATURE

Decuple terms upto *sahasra* ("thousand") frequently occur in *Ṛg-Veda*, the oldest of the four Vedas. The next term *ayuta* in the sense of "ten-

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thousand" is also found in it side by side with *sahasra* at several places especially in the Eighth Maṇḍala e.g. 1, 5 (p. 1107); 2, 41 (p. 1117); 21, 18 (p. 1185); 34, 15 (p. 1224); and 46, 22 (p. 1257). The next three (decuple) terms namely (see below) *niyuta*, *prayuta*, and *arbuda* are also found in it but none of these is said to denote a number (Satya Prakash, p. 367).

A definite list of 13 decuple terms occurs in the *Yajur-Veda* (Vājasaneyī recension), XVII, 2 (p. 270) as follows:

> eka; daśa; śata; sahasra; ayuta; niyuta; prayuta ($=10^6$); arbuda; nyarbuda; samudra; madhya; anta; and parārdha ($=10^{12}$).

We shall call this set as Medhātithi's List after the name of the associated Vedic seer. The same set is found in the *Taittirīya Saṁhitā*, IV.4, 11, 4 of the Black Yajur-Veda (Macdonell and Keith, p. 342; and Mishra, p. 17) and also in the *Śatapatha Brāhmaṇa*, IX.1, 2, 16 (*Ibid.*, p. 342; and Suryakant, p. 189).

The popularity of Medhātithi's List is also shown by the fact that with slight variations it occurs in several other places in the Vedic literature. Some references are:

(a) *Kāṭhaka Saṁhitā*, XVII, 10, where *niyuta* and *prayuta* interchange places (Macdonell and Keith, p. 342; Datta and Singh, I, 10).

(b) *Maitrāyaṇī Saṁhitā*, II, 8.14, where we have *ayuta* for 10^4 as well as for 10^6 (*Ibid.*, p. 342; and Kapadia, p. XLVIII).

(c) *Kāṭhaka Saṁhitā*, XXXIX, 6, where there is an interchange like (a) above, and then, after *nyarbuda* ($=10^8$), a new term *badva* ($=10^9$) intervenes so that the subsequent four terms take the list to 10^{13} here (*Ibid.*, 342; and Suryakant, 189).

(d) *Pañcaviṁśa*-(or *Tāṇḍa*-)*Brāhmaṇa*, XVII, 14.2 where the last four terms of Medhātithi's List are replaced by *nikharvaka*, *badva*, *akṣita*, and *go* ($=10^{12}$) respectively (*Ibid.*, 342; and Kapadia, XLIX).

(e) *Jaiminīya-Upaniṣad-Brāhmaṇa*, I.10, 28, 29, seems to replace the last four terms, like (d) above, by *nikharva*, *padma* ($=10^{10}$), *akṣiti* ($=10^{11}$), and ends with the phrase *vyomāntaḥ* which might imply a term or two (*vyoma* and *anta*) further (*Ibid.*, 342; Suryakant, 189).

(f) *Śāṅkhāyana Śrauta Sūtra*, XV, 10.7, where, similarly, the last four terms are replaced by five namely, *nikharva* or *nikharvāda* ($=10^9$); samudra; salila; *antya*; and *ananta* ($=10^{13}$) (*Ibid.*, 342; *Ibid.*, 189; Datta and Singh, I, 10).

Now we give a Vedic extension (of Medhātithi's List) which is not mentioned in many histories of Indian mathematics. According to Datta and Singh (I, 9), the *Taittirīya Saṁhitā*, VII, 2.20, contains just the above list of 13 terms. But according to Gurjar (p. 16), Ram Behari (p. 3 and cover

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page 3), and Mishra (p. 18), etc., the set of decuple terms given here extends Medhātithi's List to 7 more terms as follows:

Uṣas ($=10^{13}$); *vyuṣṭi*; *udeṣyat* (*deśyat* according to Gurjar); *udyat*; *udita*; *suvarga*; and *loka* ($=10^{19}$).

These terms are not interpreted in the above manner apparently by Macdonell and Keith (p. 342) and by Suryakant (p. 189), but Mishra (p. 18) quotes the words of the commentator, Bhattabhāskara, in support of the above numerical extension.

3. Decimal Notational Names in Scientific Works

We have already shown that Methātithi's List was not followed uniformly beyond *ayuta*. Due to vast distances and intervals of time, and also due to different Vedic schools, the names of the decuple terms varied. Sometimes the same term denoted different numbers in different texts. No care seems to have been taken to maintain the order of terms especially in the Epic literature. For instance, the *Mahābhārata*, Sabhāparva, **65**, 3–4 (Gita Press ed., Vol. I, p. 889) lines

Ayutaṁ prayutaṁ caiva śaṅkuṁ padmaṁ tathārbudam /
Kharvaṁ śaṅkhaṁ nikharvam ca mahāpadmaṁ ca koṭayaḥ //3//
Madhyaṁ caiva parārdhaṁ ca saparaṁ cātra paṇyatām /

in which Yudhiṣṭhira describes his wealth, present a complete mixing of various decuple terms.

Obviously there was a need for fixing the order of the terms and possibly standardizing the terminology. This seems to have been attempted by the authors of the astronomical and mathematical works. Āryabhaṭa I (b. 476 A.D.) in his *Āryabhaṭīya*, II, 2 (p. 33) confined to just 10 terms (why?) which are same as in Medhātithi's List upto 10^6 beyond which the former's terms are *koṭi*, *arbuda* ($=10^8$ here), and *vṛnda* ("*flock*"), the last, for 10^9. According to al-Bīrūnī (I, 176), "the book of Āryabhaṭa of Kusumapura" gives, after *koṭi*, *padma* ($=10^8$) and *parapadma* ($=10^9$).

But stopping at the tenth "order" could not be accepted especially when higher orders were already reached earlier. Also there was a need to standardize the number of terms to be given in common texts for general use. Various considerations led to favour the traditional number eighteen as the choice for the purpose. Accordingly a list of 18 decuple terms came to be accepted as the standard practice. Al-Bīrūnī (I, 174) says that the extension to the 18th order was done for "religious reasons". According to the *Viṣṇu Purāṇa*, VI, 3, 4–5 (pp. 513–514), the 18th place of counting (in decuple scale) is called *parārdha* ($=10^{17}$) which represents half of that period at the end of which there is the *prākṛta-pralaya* ("annihilation of nature") when the visible world shrinks into the invisible one.

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Whatever be that, the names upto 18th denominational place are found in standard works on Indian mathematics by Śrīdhara, Bhāskara II, etc. But who was the first to do so? Lists of "eighteen places of numeration" do appear in the Puranic literature, e.g. *Vāyu Purāṇa*, Chapter 63 (pp. 408–410) gives two sets of names. But due to uncertainty about the dates of the Puraṇas and due to their composite character, we cannot be sure of the originality of their lists.

According to al-Bīrūnī (I, 177), the *Puliśa-siddhānta* has the following names:

> *eka, daśa, śata, sahasra, ayuta, niyuta, prayuta, koṭi, arbuda, kharva, kharva* (repeated), *nikharva, mahāpadma, śaṅku, samudra, madhya, antya, parārdha.*

Half this list is same as that of Āryabhaṭa I. But then the use of *kharva* for 10th as well as for the 11th order is a confusion which is to be removed. D. Pingree (p. 186) who collected and translated the fragments of the said work is silent over the matter. He calls the work as "The Later Puliśa-siddhānta" and places it in 8th century A.D. (*Ibid.*, p. 172). Since the original forms of the above and of the *Older Puliśa-siddhānta* which is summarized by Varāhamihira (6th century A.D.) in his *Pañca-siddhāntikā*, are not extant, we cannot be sure of their contents. According to Pingree (p. 172), the *Puliśasiddhānta* mentioned by al-Bīrūnī above, was already known to Pṛthūdaka (864 A.D.).

A definite list of 18 denominational places is given by Śrīdhara who was placed circa 750 A.D. by Datta and Singh but now placed after Mahāvīra (ca. 850) by Shukla (p. XLII). Whatever be that, Śrīdhara's set of 18 names became almost the standard Indian list of 18 decuple terms which also served as a sort of ideal for subsequent writers. Of course this idealism was not confined to names of numbers only; Śrīdhara was the model for ancient Indian mathematics in general—"Gaṇite Śrīdharācāryaḥ" —as an old popular saying puts it. His list is as follows:

> *eka, daśa, śata, sahasra, ayuta, lakṣa* (or *lakṣya*), *prayuta, koṭi, arbuda, abja* (or *abda*), *kharva, nikharva, mahāsaroja, śaṅku* (or *śaṅkha*), *saritāṁ-pati, antya, madhya*, and *parārdha* ($=10^{17}$).

The Sanskrit text is found in Śrīdhara's *Pāṭī-gaṇita*, verses 7–8 (Shukla, text p. 5) and *verbatim* in his *Triśatikā*, verses 2–3. The variants *lakṣya* and *śaṅkha* are quoted by Shukla while *abda* and *śaṅkha* are found in the *Kriyākramakarī* commentary (p. 8) on the *Līlāvatī* edited by K. V. Sarma (V.V.R.I., Hoshiarpur, 1975). Similar lists are found in the following works:

(i) al-Bīrūnī's *India* (I, 175) except for the use of *nyarbuda* for *arbuda*, and of synonyms *padma, mahāpadma, samudra* for the 10th, 13th, 15th terms respectively; also *antya* and *madhya* interchange places.

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(ii) Śrīpati's *Gaṇita-Tilaka* (ca. 1040), I, 2–3 (Kapadia, p. I) except *padma* for *abja*, and *samudra* for 10^{14}.

(iii) *Līlāvatī*, verses 10–11 (pp. 11–12) of Bhāskara II (1150 A.D.) except for the use of synonyms *mahāpadma* and *jaladhi* for 13th and 15th orders respectively. The *Kriyākramakarī* (mentioned above) version gives *abda* for *abja* besides the above two changes.

(iv) The ancient anonymous commentary (Shukla, text p. 5) on *Pātīgaṇita* gives a list similar to the *Līlāvatī*. Does this indicate that the commentary is to be dated after 1150 A.D.?

(v) Hemacandra's *Abhidhāna-cintāmaṇi* (12th century), III, 537–538 (Kapadia, p. XLVIII) except *mahāmbuja* for *mahāsaroja*.

(vi) *Gaṇita-Kaumudī*, 1, 2–3 (p. 1) of Nārāyaṇa Paṇḍita (1356 A.D.) except for the use of the synonyms *saroja*, *mahābja*, and *pārāvāra* for the 10th, 13th, and 15th orders respectively. Cf. (i) above.

4. Lore of Large Numbers

While the practice of giving a list of 18 decuple terms was generally accepted by many leading Indian mathematical authors, some other scholars, especially those living in the southern part, included terms extending to very high orders. One such extended list was given by Mahāvīra (ca. 850), a Jaina writer who lived during the reign of Amoghavarṣa I, the Raṣṭrakūṭa monarch of Karnataka and Maharashtra (815–877). In his *Gaṇita-sāra-saṅgraha*, I, 63–68 (p. 8) is found a list of 24 decuple terms, the last being *mahākṣobha* ($=10^{23}$). The list is well-known (*see* Datta and Singh, I, 13; Kapadia, XVI–XVII; Shukla, transl., 2–3). Also see below.

Actually Mahāvīra could carry out the task by employing a fewer words than one would expect by resorting to the prefixes *daśa* and *mahā* ("great"). Thus he avoided *ayuta*, *niyuta* and *prayuta* by using *daśa-sahasra*, *lakṣa*, and *daśa-lakṣa* respectively. In fact, according to al-Bīrūnī (I, 176), *daśa-sahasra* and *daśa-lakṣa* were the "popular" names and their equivalents, *ayuta* and *prayuta* were "rarely used". The question arises whether Mahāvīra followed the practice because it was already popular in his times, or the daśa-system became popular because of Mahāvīra. Anyway the system is even more popular now.

Shukla (transl., 3) has brought out a big list of 36 decuple terms from the *Gaṇita-śāstra* of Pāvaḷūri Mallikārjuna. Upto 24th place, the names are same as those given by Mahāvīra except for the mutual interchange of places of *kṣoṇī* and *mahā-kṣoṇī* with the next pair of *śaṅkha* and *mahā-śaṅkha* respectively. Beyond 24th order, Mallikārjuna's terms are:

nidhi, *mahā-nidhi*, *parārdha*, *parata*, *ananta*, *sāgara*, *avyaya*, *aprameya*, *atula*, *ameya*, *bhūri*, and *mahā-bhūri* ($=10^{35}$).

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Although Shukla has not given the date and manuscript-reference, we guess that the above Mallikārjuna is same as Pāvulūri Mallana (ca. 1100?) who wrote a Telugu version or adaptation of the *Gaṇita-sāra-saṅgraha* (see *Census of the Exact Sciences in Sanskrit* under Mahāvīra). The *Gaṇita-śāstra* mentioned by Shukla may be same as that whose author is given as Mallaya (=Mallana) and which is manuscript No. 551 (in Telugu script) in E. Hultzsch's *Reports of Sanskrit Manuscripts in Southern India*, Vol. I, Madras, 1895 (see S. N. Sen's *Bibliography*, p. 140; and *Census*, A, 4, 365). According to K. R. Rajagopalan (*Bhavan's Journal* dated Nov. 15, 1959), Mallana has mentioned king Pratāparudra (1158–94) and Rājāditya's work (?) (see below). Also note another scholar, Mallikārjuna Sūri (fl. 1178) who wrote a Telugu commentary on *Sūrya-siddhānta* (and another in Sanskrit).

Now we mention another Jaina author, Rājāditya (ca. 1190 A.D.) whose *Vyavahāra-Gaṇitam* (in Kannada) extends the list of decimal place-names to 40th order. This list is not well-known to the historians of mathematics and is as follows (p. 3 of the work):

(1) *ekam*, (2) *dāham*, (3) *śatam*, (4) *sābira*, (5) *dāsābira*, (6) *lakṣa*, (7) *dālakṣa*, (8) *koṭi*, (9) *dākoṭi*, (10) *śatakoṭi*, (11) *arbuda*, (12) *nyarbuda*, (13) *kharva*, (14) *mahākharva*, (15) *padma*, (16) *mahāpadma*, (17) *kṣoṇī*, (18) *mahākṣoṇī*, (19) *śaṅkha*, (20) *mahāśaṇkha*, (21) *kṣiti*, (22) *mahākṣiti*, (23) *kṣobha*, (24) *mahākṣobha*, (25) *nadī*, (26) *mahānadī*, (27) *naga*, (28) *mahānaga*, (29) *ratha*, (30) *mahāratha*, (31) *hari*, (32) *mahāhari*, (33) *phaṇi*, (34) *mahāphaṇi*, (35) *kratu*, (36) *mahākratu*, (37) *sāgara*, (38) *mahāsāgara*, (39) *parimita*, and (40) *mahāparimita* ($=10^{39}$).

It will be seen that the first 24 names in the above list are exactly same as those given by Mahāvīra except for Kannada influence, i.e., using *dāham* (or *dā*) and *sābir* for *daśa* and *sahasra* respectively.

Lastly, we may point out that a list of 29 place-names is said to be given by Yallaya (ca. 1480) in his commentary on the *Āryabhaṭīya*, II, 2. Shukla (transl., p. 3) has already published the list. The first 24 names are same as those given by Mahāvīra except that Yallaya goes back to the *ayuta* and *prayuta* for *daśasahasra* and *daśalakṣa* respectively; and, like Pāvaḷūri Mallikārjuna, the pair *kṣoṇī* and *mahākṣoṇī*, interchanges places with the pair *śaṅkha* and *mahāśaṅkha* respectively. Beyond 24th, the terms are: *parārdha*, *sāgara*, *ananta*, *cintya*, and *bhūri* ($=10^{28}$). Yallaya belonged to Skandasomeśva (in Āndhra region) and was influenced in giving his list by the Telugu writer Pāvaḷūri Mallikārjuna rather than the Kannada writer Rājāditya. Yallaya points out that some people use the term *saṅkṛti* for *parārdha* ($=10^{24}$), and makes the surprising statement that the people

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of Āndhra and Karṇataka "call the number 10^{10} (*arbuda*) by the denomination *śatakoṭī*" which is otherwise equal to 10^9 only (see *Āryabhaṭīya* (pp. XLIII–XLIV).

In the end we mention that Kapadia (pp. XX and XLIX) has quoted a peculiar list of 24 decuple terms from a Buddhist work called *Abhidhānappadīpikā*, and another (incomplete) list of 60 decuple terms from Rahula Sankrtyayan's commentary on Vasubandhu's *Abhidharmakośa*, III, 94. We leave these for a future discussion.

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Dissertation Abstract

गणित एवं ज्योतिष के विकास में जैनाचार्यों का योगदान
(पीएच० डी० शोधप्रबन्ध का सारांश)

MUKUT BIHARI LAL AGRAWAL

15/249, Charsu Darwaza, Agra

Presented below is a summary of M. B. Lal Agrawal's Ph.D. Thesis entitled "Contribution of the Jainācāryas to the Development of Mathematics and Astronomy" (in Hindi). The Thesis was successfully completed (Agra University, 1972/73) under the supervision of K. S. Shukla. It has three main parts: Part I is on the "Sources of Jaina Mathematics" and is divided into four chapters. Part II is on "Jaina Mathematics" and is further divided into nine chapters. Part III is on "Jaina Astronomy" and contains four chapters. There is also the "Bhūmikā" (a sort of introduction) and three Appendices at the end. The whole work is a comprehensive and critical survey of Jaina school of Indian mathematics and astronomy (especially cosmography). Topics discussed include numbers and numerals, arithmetic, algebra, geometry, series, etc. and some comparative studies of other Indian astronomical theories.

—Editor (RCG)

सम्पूर्ण शोध प्रबन्ध को अध्ययन की सुविधा हेतु मूलतः तीन खण्डों में विभक्त किया गया है। प्रथम खण्ड को जैनगणित के स्रोत की संज्ञा से अभिहित किया गया है। इसके अन्तर्गत 'भारतीय गणित', 'भारतीय गणित के इतिहास में जैन गणित परम्परा का योगदान', 'सिद्धान्त शास्त्रों में विकसित गणित', और 'महावीराचार्य का सारसंग्रह'—ये चार अध्याय हैं। द्वितीय खण्ड जैन गणित के नाम से पुकारा गया है जो नौ अध्यायों का समाहित रूप है। ये अध्याय इस प्रकार हैं—'संख्या तथा संकलनादि सूचक संकेत', 'जैन साहित्य में भिन्न', 'त्रैराशिक तथा मिश्रानुपात', 'क्षेत्रगणित', 'जैन साहित्य में बीजगणित', 'जन्य क्षेत्रों में बीजगणित का अनुप्रयोग', 'जैन गणित में श्रेढ़ी व्यवहार', 'जैन साहित्य में क्रमचय एवं संचय', और 'अलौकिक गणित'। तृतीय खण्ड 'जैन ज्योतिष' के विषय से सम्बद्ध है जिसको चार अध्यायों में विभक्त किया गया है। ये अध्याय इस प्रकार हैं—'ज्योतिष', 'भूमण्डल', जैन-साहित्य में वर्णित लोक' और 'ज्योतिर्लोक'। प्रत्येक खण्ड में वर्णित अध्यायों को भी उप-शीर्षकों में विभक्त करते हुए विषय सामग्री को प्रतिपादित किया गया है। अतः सम्पूर्ण शोध प्रबन्ध का सारांश अध्यायों के सारांशों के माध्यमों से प्रस्तुत करते हैं।

प्रथम खण्ड

अध्याय १ (भारतीय गणित)

गणित शब्द की व्युत्पत्ति एवं अंक ज्ञान के विषय में तात्कालिकता को समाविष्ट किया

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गया है। तात्कालिकता की प्रामाणिकता के लिए समुचित उद्धरण भी प्रस्तुत किये गये हैं। वैदिक साहित्य, प्राकृत साहित्य, अपभ्रंश साहित्य, जैन साहित्य की महती सहायता लेते हुए विषय के प्रतिपादन में तथ्यता को पूर्णतः समाहित किया गया है। विषय की पुष्टि के लिए मूल उदाहरणात्मक श्लोकों, कथनों की प्रस्तुति करते हुए मूल विषय को प्रामाणिक बनाने की चेष्टा का सतत ध्यान रखा गया है। भारतीय गणित का स्वरूप जो अभी तक किसी सीमा तक अन्धकार के गर्भ में है उसको प्रकाश में लाने का प्रयत्न किया गया है। देशी और विदेशी विद्वानों की अभिधारणाओं के आधार पर प्रस्तुत विषय का प्रतिपादन सम्भव हो सका है। भारतीय गणित का विकास एक महत्वपूर्ण विषय है क्योंकि भारत गणित शास्त्र में सानी नहीं रखता। भारत का गणित अनादिस्वरूपा है। इसलिए इसके संक्षिप्त एवं क्रमिक इतिहास की अपेक्षा अपना अत्यधिक महत्व रखती है। इस वास्तविकता को ध्यान में रखते हुए प्रस्तुत अध्याय को समृद्धिशाली बनाने का प्रयास किया गया है।

अध्याय २ (भारतीय गणित के इतिहास में जैनगणित परम्परा का योगदान)

इस अध्याय में भारतीय गणित के विकास में जैनगणित ने किस प्रकार का परम्परात्मक योगदान दिया है—पूर्णतः विवेचित है। इस विवेचना में जैनगणित के उदय पर प्रकाश डालते हुए तात्कालिक विन्दु पर खड़े होकर पूर्वकालिक और परकालिक गणित के विकासात्मक इतिहास का चित्र सम्मुख रखा गया है। जैनगणित, जो जैनशास्त्रों में प्रतिष्ठित है, बताती है कि भारतीय गणित में कितना प्राचीनत्व है और स्वयं का क्या स्थान है—इस कथन की वास्तविकता को प्रस्तुत अध्याय में मूल संस्कृत श्लोकों, प्राकृत एवं अपभ्रंश के उदाहरणों के साथ यथोचित रूप में प्रस्तुत किया गया है। जैनगणित के विषय-वैविध्य पर विचार करते हुए जहाँ जैनगणित के अध्ययन के आधार प्रस्तुत किये गये हैं, वहाँ जैन-गणित की ऐतिहासिकता पर विचार करते हुए भारतीय गणित की ऐतिहासिकता पर विचार किया गया है। जैनगणित के विषय-वैविध्य पर विभिन्न जैन तथा अजैन विद्वानों के मतों को प्रस्तुत करते हुए उनके समचीनत्व पर प्रकाश डालते हुए भारतीय गणित के इतिहास में जैन-गणित परम्परा के योगदान का मूल्यांकन किया गया है।

अध्याय ३ (सिद्धान्तशास्त्रों में विकसित गणित)

इस अध्याय के अन्तर्गत विभिन्न सिद्धान्तशास्त्रों में गणित किस-किस रूप में विद्यमान है और ये किस प्रकार विकासात्मक दिशागमन में प्रेरक सिद्ध हुए हैं—इसकी विवेचना का अध्ययन किया गया है। प्रस्तुत अध्याय में जो अध्ययनात्मक विवेचन है उसके आधार ये सिद्धान्तशास्त्र हैं—'तत्त्वार्थाधिगमसूत्र और उसकी टीकाएँ', 'तिलोयपण्णत्ति', जम्बूद्वीव-पण्णत्ति', 'धवलाटीका', 'गोम्मटसार' तथा 'त्रिलोकसार'। प्रत्येक सिद्धान्तशास्त्र के प्रणेता, कालावधि आदि पर विचार करते हुए गणितमयी विशेषताओं का प्रतिपादन किया गया है। जहाँ तक सम्भव हो सका है, एक सिद्धान्तशास्त्र का दूसरे सिद्धान्तशास्त्र के साथ क्या साम्य है और क्या असाम्य है, इसको बताते हुए अपने विषय को उपयुक्तता प्रदान की गयी है। गणित के जितने भी अध्ययन के तत्व हैं उनका भी उपर्युक्त कथन के आधार पर मीमां-सात्मक विवेचन उद्धरण सहित किया गया है।

अध्याय ४ (महावीराचार्य का गणितसार संग्रह)

प्रस्तुत अध्याय में महावीराचार्य की गणितज्ञता पर विचार करते हुए जैनगणित

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परम्परा में आचार्य जी का किस सीमा तक योगदान रहा है और गणित के सुव्यवस्थित रूप-प्रतिपादन में वे कहाँ तक सफल रहे हैं का विवेचन दर्शनीय है। वस्तुतः महावीराचार्य जी के नौ अध्यायों से सम्पन्न इस ग्रन्थ में जैनगणित के प्रारूप को विस्तार प्रदान किया गया है। प्रथम अध्याय का श्रीगणेश आचार्य जी ने मंगलाचरण करते हुए गणितशास्त्र की प्रशंसा से किया है। तदुपरान्त गणित की मुख्य क्रियाओं के नामों, राशियों, नियमों और स्थान नामावली को स्पष्ट किया है। इस ग्रंथ का द्वितीय अध्याय जोड़, बाकी, गुणा, भाग, वर्ग, वर्गमूल, घन, घनमूल के विवेचन से सम्बद्ध है। इस ग्रन्थ के तृतीय अध्याय में भिन्न के स्वरूप को उदाहरणों सहित प्रस्तुत किया गया है। चतुर्थ अध्याय प्रकीर्णक व्यवहार के विवेचन से अपना सम्बन्ध बनाये हुए है। भिन्नों पर विविध प्रश्नों का विवेचन समुचित उद्धरणों के द्वारा सम्मुख रखा गया है। 'त्रैराशिकता' इसका पंचम अध्याय है। इसमें जितने भी नियम सम्भव हो सके हैं उनका सोदाहरण स्पष्टीकरण किया गया है। इस ग्रन्थ का छठवाँ अध्याय मिश्रक व्यवहार के विवेचन से सम्बद्ध है। विषय की पुष्टि के लिए यथोचित उदाहरणों का प्रयोग किया गया है। सप्तम अध्याय में क्षेत्रगणित की व्यावहारिकता पर प्रकाश डालते हुए इसके महत्व को प्रतिपादित किया गया है। 'खात व्यवहार'—यह प्रस्तुत ग्रन्थ का आठवाँ अध्याय है। इसमें आचार्य जी ने समुचित उदाहरणों से विषय की मार्मिकता को सम्मुख रखा है। इस ग्रन्थ का अन्तिम अध्याय 'छाया व्यवहार' नामक नवम अध्याय है। छाया व्यवहार की पारिभाषिकता को सम्मुख रखते हुए इसके महत्व को प्रतिपादित किया गया है। अतः कहा जा सकता है कि आचार्य जी के इस ग्रन्थ ने जैनगणितशास्त्र के स्थायित्व में तो पूर्णतः योगदान दिया ही है, साथ ही साथ भारतीय गणित के इतिहास को भी सबलता प्रदान की है।

द्वितीय खण्ड

अध्याय १ (संख्या तथा संकलनादि सूचक संकेत)

इसके अन्तर्गत संख्या की परिभाषा को व्याकरण शास्त्र के आधार पर स्पष्ट करते हुए गणितशास्त्र के परिप्रेक्ष्य में उसके स्वरूप को स्पष्ट किया गया है। विभिन्न आचार्यों के पारिभाषिक परिवेशों को प्रस्तुत करते हुए जैनाचार्यों के मतों के अनुसार संख्या की परिभाषा का समुचित रूप प्रस्तुत किया गया है। इस अध्याय की यह विलक्षणता है कि जैनाचार्यों के मतों के आधार पर यह सिद्ध किया गया है कि एक की गिनती संख्या नहीं है। अंकों के तीन वर्गों में विभाजन पर विचार करते हुए कृति में जो नवीन है, उसके प्रारूप पर स्पष्टतः विचार किया गया है। संख्यालेखन भी प्राचीनतम है—इस विषय पर विभिन्न शास्त्रियों एवं आचार्यों ने अपने-अपने दृष्टिकोण से विचार किया है। जैनगणित और ज्योतिष में इसकी अपनी क्या स्वरूपता है—इस अध्याय का मूलतः अभिप्रेत है। संख्यालेखन के विषय को पुष्ट प्रमाणों के आधार पर प्रस्तुत किया गया है। जैन साहित्य में विशाल संख्याएँ किन-किन ग्रन्थों में समाहित हैं—इस पर विचार करते हुए उनका स्पष्टतः उल्लेख किया गया है। 'अंकों की लिखावट' भी इस अध्याय का महत्वपूर्ण अंग है। अंक-लिखावट की प्राचीनता पर समुचित विवरणात्मक तालिकाओं द्वारा विचार किया गया है। गणितशास्त्र में संकलनादि सूचक संकेत अपना विशेष महत्व रखते हैं। अतः संकलनादि सूचक संकेत की महत्ता पर

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विचार करना परम कर्त्तव्य हो जाता है। प्रस्तुत अध्याय के अन्त में संकलनादि सूचक संकेत का स्पष्टतः विचार दृष्टव्य है।

अध्याय २ (जैन साहित्य में भिन्न)

यह अध्याय, जैन साहित्य में भिन्न का स्वरूप किस प्रकार निहित है, इसका एक स्पष्ट परिचायक है। भिन्न की प्राचीनता पर विचार करते हुए जैन वाङ्मय में बड़ी-बड़ी भिन्नों के व्यापक प्रयोगों पर मनन किया गया है। भिन्न-लेखन को स्पष्ट करते हुए आंशिक भिन्न और रूपांशक भिन्न की वास्तविकता की अभिव्यंजना करते हुए, उनसे सम्बद्ध प्रश्नों का उल्लेख भी किया गया है। भिन्नों में अपवर्तन (सरलीकरण) अपना विशिष्ट महत्व रखता है। भिन्नों के अपवर्तन की पूर्णता को विभिन्न दृष्टिकोणों से प्रस्तुत करके उसकी महत्ता का मूल्यांकन किया गया है। भिन्नों के गुणन एवं भाग के विषय पर भी विचार दर्शनीय है। भिन्नों के वर्ग, घन, वर्गमूल और घनमूल पर विचार करते हुए बड़ी-बड़ी भिन्नों के निकटतम मान पर समुचित विचार किया गया है। विततं भिन्न को सोदाहरण स्पष्टतः विवेचित किया गया है। अध्याय के अन्त में हिन्दू गणितज्ञों ने भिन्नों के वर्गीकरण पर जो विचार रखे हैं, उनका भी उदाहरण सहित विवेचन किया गया है।

अध्याय ३ (त्रैराशिक तथा मिश्रानुपात)

त्रैराशिक शाब्दिकता पर विचार करते हुए उसकी प्राचीनता, प्रयोगशीलता एवं महत्ता का विवेचन दर्शनीय है। व्यस्त त्रैराशिकता को भी पुष्ट उदाहरणों के आधार पर स्पष्ट किया गया है। मिश्रानुपात पर विचार इस अध्याय का अन्तिम रूप है। हिन्दू गणित में मिश्रानुपात के विषय में जो चर्चा की गयी है उसकी प्रासंगिकता को सम्मुख रखते हुए मिश्रानुपात के स्वरूप पर स्पष्टतः विवेचन किया गया है। विवेचन की पुष्टि के लिए यथोचित पुष्ट कथन एवं उदाहरण भी प्रस्तुत किये गये हैं।

अध्याय ४ (क्षेत्रगणित)

इस अध्याय में क्षेत्रगणित के उद्गम एवं प्रकारों को प्रासंगिक पुष्ट कथनों के आधार पर स्पष्ट किया गया है। विषय को सुस्पष्ट एवं सुगम बनाने के लिए आकृतियों की सहायता ली गयी है। क्षेत्रमापन की इकाइयों पर भी विचार किया गया है। वृत्तगणित-सम्बन्धी शब्दों को स्पष्ट करते हुए इसके सूत्रानेकत्व (वृत्तगणित से सम्बन्धित जितने भी सूत्र हैं) पर विभिन्न ग्रन्थों से लिये गये प्रसंगों के आधार पर विचार किया गया है। क्षेत्रगणित के सूत्रों में π (पाई) का व्यापक प्रयोग होता है। इसलिए π के स्वरूप एवं मान पर विचार करना अपने में महत्वपूर्ण है। इस अध्याय के अन्तर्गत π के मान पर स्पष्टतः विचार किया गया है। विभिन्न आकार के क्षेत्रों तथा उनमें प्रयुक्त होने वाले सूत्रों पर स्पष्टतः चित्रात्मक विचार एवं उनके हल करने की विधियाँ दर्शनीय हैं। अध्याय के अन्त में आयतन जैसे विषय में प्रयुक्त होने वाले सूत्रों पर विचार करते हुए सूत्रों की पुष्टि हेतु समुचित उदाहरणों एवं आकृतियों की सहायता ली गयी है।

अध्याय ५ (जैन साहित्य में बीजगणित)

यह एक महत्वपूर्ण अध्याय है। प्रारम्भिक जैन ग्रन्थों में बीजगणित का क्या स्वरूप था—इस पर विचार करते हुए बीजगणित के अन्तर्गत प्रयुक्त चिह्नों एवं उनके नियमों पर स्पष्टतः

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विवेचन किया गया है। बीजगणित के अन्तर्गत समीकरण की महिमा यत्र-तत्र सर्वत्र देखी जाती है। अतः समीकरण की महत्ता को देखते हुए प्रस्तुत अध्याय में समीकरण को प्रत्येक दृष्टिकोण से देखा गया है और विविध प्रकारों को समुचित उदाहरणों द्वारा स्पष्ट किया गया है।

अध्याय ६ (अन्य क्षेत्रों में बीजगणित का अनुप्रयोग)

विषय के स्वरूप को स्पष्ट करते हुए समकोण त्रिभुज के विभिन्न जननों का विवेचन सोदाहरण प्रस्तुत करना अपने में एक अभीष्ट रहा है। क्षेत्रफल तथा भुजाओं से सम्बद्ध समस्याओं के अन्तर्गत आयतों, वर्गों तथा चतुर्भुजों पर विचार करते हुए उनकी सूत्रात्मकता को उदाहरणों द्वारा पुष्ट किया गया है।

अध्याय ७ (जैनगणित में श्रेढी व्यवहार)

इस अध्याय के अन्तर्गत बीजगणित में श्रेढी व्यवहार की महत्ता पर विचार किया गया है तथा यथोचित उदाहरणों के द्वारा उनको पुष्टि प्रदान की गयी है। श्रेढियों की विविधता की समुचित विवेचना की गयी है। श्रेढियों के नामकरण में जो विभिन्नत्व है, उस पर स्पष्टतः विचार किया गया है तथा विविध श्रेढियों के हलों पर प्रकाश डाला गया है।

अध्याय ८ (जैनगणित में क्रमचय एवं संचय)

क्रमचय एवं संचय नामक गाणितिक विषय पर विचार करते हुए उनके नामकरण पर विस्तार से विवेचन किया गया है। क्रमचय एवं संचय में प्रयुक्त होने वाले सूत्रों का विवेचन गणित ग्रन्थों की प्रासंगिकता के आधार पर किया गया है। तथा उनके हल करने की विधियों की प्राचीनता को स्पष्ट करते हुए समुचित उदाहरणों के द्वारा सूत्रों की प्रयोगशीलता का दिग्दर्शन कराया गया है। विषय को सुगम बनाने के लिए सरस उदाहरणों को प्रस्तुत किया गया है।

अध्याय ९ (अलौकिक गणित)

प्रस्तुत अध्याय शोध प्रबन्ध के द्वितीय खण्ड का अन्तिम अध्याय है। इस अध्याय के अन्तर्गत हिन्दूगणित में जो जैनगणित की विलक्षण, अपूर्व एवं मौलिक देन है, उसका वर्णन किया गया है। वस्तुतः इस मौलिक गणित को 'अलौकिक गणित' की संज्ञा से अभिहित किया गया है। अलौकिक गणित के स्वरूप पर विचार करते हुए उसके भेदों और संख्यामान की विविधताओं को चित्रों एवं गाणितिक विवेचन के द्वारा सुस्पष्ट किया गया है। संख्यामान को विभिन्न जैन आचार्यों के कथित मतों के द्वारा पुष्ट किया गया है। इतना ही नहीं, अपितु उसमें सूत्रों का भी प्रयोग यथोचित रूप से किया गया है। उपमामान की परिभाषा करते हुए भेदों पर प्रकाश डाला गया है। विभिन्न भेदों की व्याख्या श्वेताम्बर एवं दिगम्बर दोनों मतों के आधार पर की गयी है।

तृतीय खण्ड

अध्याय १ (ज्योतिष)

इसके अन्तर्गत ज्योतिष शब्द की व्याख्या करते हुए जैन ज्योतिष के उद्भव और विषय पर विचार किया गया है। जितने भी गणित सिद्धान्त हैं उनकी निहिति ज्योतिष परि-

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कर्मों में है। इस दृष्टि से यह अत्यन्त अपेक्षित हो जाता है कि जितने जैन एवं जैनेतर ग्रन्थ हैं उनकी ज्योतिष के आधार पर तुलना की जावे। अतः इस अध्याय में इस दृष्टिकोण पर व्यापक प्रकाश डाला गया है। ज्योतिष के जितने भी अध्ययन-अपेक्षित ग्रन्थ हैं उन पर विचार करते हुए उनकी ऐतिहासिक महत्ता भी विवेचित की गयी है। जैन ज्योतिष साहित्य का काल-विभाजन करते हुए विविध कालों में प्राप्त ज्योतिष कृतियों पर भी प्रकाश डाला गया है।

अध्याय २ (भूमण्डल)

वैदिक मत, बौद्ध मत, आधुनिक मत और जैन मत के आधारों पर भूमण्डल की विस्तृत विवेचना की गयी है। अध्ययन को सुस्पष्ट एवं सारगर्भित बनाने के लिए उपर्युक्त मतों का तुलनात्मक अध्ययन भी किया गया है जिससे विषय को स्पष्टत्व प्राप्त हुआ है। अपने सम्पूर्ण विवेचन को पुष्टिमय बनाने के लिए प्रासंगिक कथनों का भी उल्लेख किया गया है।

अध्याय ३ (जैन साहित्य में वर्णित लोक)

विश्व शब्द की शाब्दिक व्याख्या करते हुए लोक किन-किन द्रव्यों से बना है, उन पर प्रकाश डाला गया है। लोक के निर्माण में सहायक द्रव्यों का विवेचन जैन साहित्य के आधार पर तो किया ही गया है परन्तु उसका वैज्ञानिक अध्ययन भी इस अध्याय की अपनी निजी विशेषता है। प्रस्तुत अध्याय में लोक के आकार पर विस्तृत विचार किया गया है। लोक का आयतन उपमा द्वारा समझाते हुए गाणितिक आधार पर उसकी पुष्टि की गयी है। गाणितिक विवेचन के अन्तर्गत श्वेताम्बरी एवं दिगम्बरी परम्पराओं पर विचार करते हुए दोनों के मतभेदों को स्पष्ट किया गया है और समुचित मूल्यांकन किया गया है। इस अध्याय के अन्त में जैन आधार पर वर्णित लोक और वैज्ञानिक विश्व की स्पष्टतः विवेचना की गयी है तथा उसकी प्रारूपता का मूल्यांकन किया गया है।

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अध्याय ४ (ज्योतिर्लोक)

इस अध्याय के अन्तर्गत ज्योतिर्लोक की स्थिति पर विचार किया गया है और अपने विचार को स्थायित्व प्रदान करने के लिए वैदिक मत, बौद्धमत, आधुनिक मत और जैन मत की अवधारणाओं की महती सहायता ली गयी है। ज्योतिर्लोक में विद्यमान ग्रहों एवं उपग्रहों की विवेचना भी दर्शनीय है।

शोध की मुख्य सामग्री उपर्युक्त तीन खण्डों में निहित है। उनके अतिरिक्त शोध प्रबन्ध के प्रारम्भ में 'भूमिका' में शोध प्रबन्ध के विषय का महत्व इत्यादि की चर्चा की गयी है। शोध-प्रबन्ध के अन्त में तीन परिशिष्ट हैं जिनमें क्रमशः भूत संख्याओं की तालिका, हस्त-लिखित जैन ग्रन्थों से संग्रहीत अंक, और सहायक ग्रन्थों की सूची है।

पुस्तकालय पुस्तकालय गुरुकुल कांगड़ी विश्वविद्यालय
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Ganita-Bharati
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MEETINGS

1981/82 Meetings of the British Society for History of Mathematics

(Report by A. J. Crilly, Secy., B.S.H.M.)

The Annual General Meeting of the British Society for History of Mathematics was held on December 21, 1981 at King's College, London. The following were elected as officers of the Society:

Dr. H. G. Flegg (President); Dr. F. R. Hickman (Treasurer); Dr. A. J. Crilly (Secretary); Leo Rogers (Librarian); Prof. C. W. Kilmister, Prof. G. Whitrow, and R. Gowing (Committee Members).

There were addresses by Prof. R. L. Plackett (Univ. of Newcastle) who spoke on "Karl Pearson and the Chi-Squared Test", and Dr. A. W. F. Edwards (Univ. of Cambridge) who spoke on "The Problem of Points: Pascal-Fermat correspondence".

A Saturday meeting of the B.S.H.M. was held at the London Science Centre on June 26, 1982 on the theme 'Women Mathematicians'. Two invited talks delivered were the one on "The Pioneering Women Mathematicians" by Garry J. Tee (Univ. of Auckland) and the other on "Sonya Kovalevskaya and Partial Differential Equations" by Dr. R. L. Cooke (Univ. of Vermont).

The Annual Conference of the Society was held at Gonville and Caius College, Cambridge on September 10–12, 1982. A major theme was 'Mathematics Education'. The speakers and titles of their talks were:

1. David Pimm (Univ. of Nottingham), "Implications of the History of Mathematics for Mathematics Education".
2. Leo Rogers (Digby Stuart College), "Mathematics in Education (Britain 1780–1850)".
3. M. Price (Nene College), "Mathematics in Education (Britain 1850–1914)".
4. P. Bursill-Hall (Univ. of Cambridge), "Calculus taught in the 18th Century France".
5. Li Wen-Lin (Inst. of Math., Beijing), "The background of the native Mathematics in China".
6. A. E. L. Davis, "Kepler's theoretical contribution to the development of the calculus".

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7. G. J. Tee (Univ. of Auckland), "Relics of Charles Babbage in Australia".
8. D. T. Whiteside (Univ. of Cambridge), "Some Historical Aspects of Curve Sketching" (an impromptu talk with the aid of a micro-computer).

Jambū-Dvīpa Seminar 1982

(A brief report by Anupam Jain, Organising Secy.)

A seminar related to Jaina mathematical astronomy, cosmography and geography was held at Delhi under the auspices of the D. J. Institute of Cosmographic Research, Hastinapur (Meerut) from October 31 to November 2, 1982. The Seminar was graced by the presenee of the Jain Saint-scholar Āryikāratna Jñānamatī, and Prof. L. C. Jain (Govt. P. G. College, Chindwara) was the leader of academic programme. The inaugural talk was delivered by Shri Rajiv Gandhi.

Eight sessions were held in which about 30 research papers were presented. Ten invited talks were also delivered. The speakers include Dr. S. D. Sharma (Panjabi Univ., Patiala), Dr. S. R. Sinha (Mehta Research Inst., Allahabad), Dr. S. S. Lishk (Govt. Inservice Training Centre, Patiala), Takao Hayashi (Research Fellow, National Science Foundation), etc.

It was decided to hold an international seminar on Jaina school of mathematics.

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BOOK REVIEWS

Code of the Quipu: A Study in Media, Mathematics, and Culture

by MARCIA ASCHER and ROBERT ASCHER
University of Michigan Press, Ann Arbor, 1981, x + 166 pp.
Paperback $ 8.95, cloth $ 18.95.

Reviewed by PHILLIP S. JONES, *University of Michigan, Ann Arbor, Michigan 48109, U.S.A.*

There continues to be so much of mystery about the precolumbian civilizations, especially the mathematics of the Mayans and Incas, that any additions to our knowledge of them are welcome. New insights and conjectures thoughtfully supported may become the basis for further theories, perhaps even for discovering more of the motives, content, and processes of their mathematics.

This book stresses interpretations which may be made of Inca quipus. It is based on the results of a world-wide search for all existing quipus. A bibliography and extensive data on the one hundred ninety-one which were located is contained in the *Code of the Quipu Databook* published in 1978 and now available on microfiche. The book reviewed here contains photographs of eight and discussions of thirty quipus.

The first four chapters present brief interesting outlines of the role of the Incas, how to make a quipu (even including a device conjectured by the authors for spinning the yarn), speculations on the role of the quipu-maker in the Inca culture and on what quipus imply with respect to the nature of that culture.

The remaining four chapters expound the authors' views that quipus and their possible uses not only reveal the Inca culture to have been systematic and orderly but to have come further toward having the equivalent of a written language than has commonly been credited to them. Those conjectures are supported by elaborating how the quipu could have been used not only for recording numbers such as census data, but also for accounting, calendrics, and recording oral history, peace negotiations, and laws. The authors show that the hierarchical arrangement of the elements appearing in the quipus studied could be used to display quite complicated relationships as well as numbers. The elements include the arrangement of

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pendant cords above and below a main cord, subsidiary pendants, different kinds of knots and of coloured yarns.

Although there seems to be no direct representation of numbers other than integers, the authors' analyses suggest that ideas of proportion are implicit in a number of quipus. They suggest that these ideas may have been associated with either the analysis of existing relationships or the planning of new structures or relationships. They see interesting geometrical connections, some related to the golden section. A historian of mathematics might prefer to modify a few of the assertions about early Greek concepts of fractions and concern for irrationals in this last chapter, but the book provides much data on quipus and develops some interesting conjectures as to their possible use. It includes exercises, and answers, to help the reader develop an understanding of these relationships.

Mathematicians and Their Times: History of Mathematics and Mathematics of History

by LAURENCE YOUNG; North Holland Publishing Co., Amsterdam and New York, 1981; pp. vii + 344; U.S. $ 36.50.

Reviewed by P. C. VAIDYA, *Gujarat University, Ahmedabad-380 009*

This is a volume in a series of paperback tutorials in pure and applied mathematics, and it is written in the style of tutorials. It is the outcome of lectures given at the University of Wisconsin by the author who is basically a mathematician, but who however believes that it is not enough to study the latest developments but "we have to go back to the sources with a professional 20th century outlook to find what manner of men were able to plant the seed and what difficulties and prejudices they had to overcome". This, in essence, explains the title of the book, the emphasis being on mathematicians and circumstances in which they created their mathematics.

The author, himself a distinguished mathematician, had equally distinguished mathematician-parents. He thus had ample opportunities of personally knowing several mathematicians of the last decade of 19th century upto the present day and we have almost a personal account of these acquaintances in the pages of this book.

If one opens the book with the preconceived notion of reading a book

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on History of Mathematics, one is likely to be disappointed. It is not a book on History of Mathematics. It is a book on mathematicians and their mathematics. As the author says, there is an area called Mathematics of History and on reading the book one gets the impression that it is a book on mathematics without many symbols or formulae, a book dealing with history of Mathematics with the help of mathematics of History!

The socio-political impact of prevailing circumstances on creative mathematicians has been described with the help of what are called 'bends'. This has reference to a situation arising in deep sea diving. It is a miracle how human tissues (of the diver) stand up to terrific under-water pressure. The tissues fill themselves up with nitrogen or at greater depth with helium at a rate given by a definite mathematical law. (Incidentally, the author of this book had a share in deriving this law!) If the diver suddenly comes to the surface he would suffer the 'bends' which would kill him. When the outside pressure is suddenly reduced, the inside pressure developed in the tissues remains, the diver virtually explodes. A society faces similar situations, for example, with a 'sudden outbreak of peace'. Such 'bends' are one of the great forces of history and society must learn to control them just as we do in case of divers. Such bends have occurred at various stages in the history of peoples and they have had effects on creative capabilities of individuals and so of mathematicians. This is clearly brought out in the three hundred and odd pages of this book.

The contents of the book are divided into an Introduction (123 pages) and three chapters (covering 214 pages between them). The reason for this sort of division is best expressed by the following quotation from the text: "There are excellent and detailed works on the history of mathematics upto about 1800. They deal with what I prefer to call the infancy of mathematics. The standard work is that of Moritz Cantor; *Geschichte der Mathematik*; I have a slight preference for Loria: *Storia delle Mathematiche*, because its author is a mathematician—a geometer reasonably well known in his time. There are a number of other works, most of which I shall not even cite, since I intend to give of this whole period of infancy only the briefest of outlines. We can learn more, I think, from the past two hundred years, with perhaps an occasional flash back."

Thus the Introduction contains a brief survey of mathematicians and their times upto about 1800. Chapter I begins with a 'bend'—the French Revolution—and is entitled 'The Romantic Period'. The period extends roughly upto 1900 and marks the slow evolution of rigour in mathematical analysis. The chapter (95 pages) contains a readable account of achievements of great men as well as many errors they committed and discouragements they had to struggle with.

Chapter II (32 pages) deal with the advent of set theory in mathematics

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and mainly deals with George Cantor and his time. It is aptly titled 'Concepts and Reality'. While chapter I described the role of institutions like École Polytechnique and École Normale in France and the Cambridge Tripos examinations in England in shaping up the mathematicians of the period, chapter II describes the rise of the Goettingen School.

In the third and the last chapter (90 pages) the author leads us into the twentieth century—the period marked by two 'bends'—the two world-wars. On reading this chapter one hardly feels that one is reading a chapter in history of mathematics because the mathematicians described appear so near us and their times overlap with our own times. As a matter of fact author seems to have the personally known almost all mathematicians mentioned in this chapter.

The book ends with an Index of persons. A very readable book for both mathematicians as well as historians!

The Collected Letters of Colin Maclaurin

Edited by STELLA MILLS (Shiva Publishing House, London, 1982), pages xx + 496, £ 15.00.

Reviewed by J. N. KAPUR, *Indian Inst. of Technology, Kanpur 208016.*

The present collection contains 115 general and 103 scientific letters written by either the famous Scottish mathematician Colin Maclaurin, FRS (1696–1746) to his friends or from his friends to him.

The general letters give an idea of the Society and the times in which Maclaurin lived and worked. However, historians of Mathematics and Science will find the 103 scientific letters covering 312 pages a veritable treasure house of information on the contributions of Maclaurin to Mathematics, on his relations with other mathematicians like Sir Isaac Newton, James Stirling, John Machin and Alexis Clairaut, on the manner in which new results in mathematics were communicated through personal correspondence and the excitement in Mathematics and Science that was responsible for the great renaissance in mathematics in the first half of the eighteenth century in England, Scotland and France.

Every student of Mathematics, from higher secondary school onwards, has heard of Maclaurin's theorem and Maclaurin's series. These letters

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bring out his other contribution to theory of curves, theory of algebraic equations, to the development of the calculus and to extension of the work of Newton. In fact Newton held Maclaurin in high esteem and got him elected to the fellowship of the Royal Society. On his part, Maclaurin appears as a great expositor of Newton's work and as a great defender of his methods against critics like Bishop Berkley. Maclaurin's Theory of Fluxions was considered a masterpiece even at that time.

The following excerpts from some of the letters of Maclaurin will give one an idea of the flavour of the book:

(i) "That which I had most in my view throughout all the discussion was the establishment of the universality of the law of gravity and the necessity of referring it to a first cause, the first because it is a most pleasant entertaining truth in Natural Philosophy, the other because it is of the greatest importance and use seeing it furnishes us with a most clear and mathematical proof of the existence of a God and his providence that he not only made the world and he rules and governs it concerning himself in the affairs of it being present everywhere in working that which is best for the inhabitants of it."

(ii) "Since I have mentioned the uses of Mathematics, I shall beg your pardon for troubling you with some thoughts I have relating to their use in morality."

(iii) "When I went through Newton's *Principia*, I found out fluxional demonstrations of many of his propositions."

(iv) "In any cubic equation, all of whose roots are real, the square of the second term is always greater than the triple product of the first and third and the square of the third term must be greater than the triple product of the second and fourth terms. In a biquadratic equation, all of whose roots are real, 3/8 of the square of the second term is always greater than the product of the first and third term and 3/8 of the square of the fourth term is always greater than the product of third and fifth terms."

The editor Dr. Stella Mills has done a painstaking job and has made the task of the reader much easier by her extensive foot-notes, historical introduction and index and the translations of the letters which were originally in French.

The editing and publication of this work was financed by Scottish universities since this work brings to light the work of a great Scottish mathematician. The Indian Commission for the Compilation of History of Sciences in India, of which the present reviewer has the privilege of being a member, is doing similar work in India. However, it should take special care to preserve the scientific correspondence of present-day mathematicians and scientists lest these be lost to posterity. In fact all universities and professional societies like the Indian Society for the History of Mathematics should jealously guard such documents. The reviewer was recently shocked

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to learn that the Bose-Einstein correspondence which gave rise to Bose-Einstein statistics has already gone out of India. I believe we should take steps to collect scientific letters of Ramanujan, Vaidyanathswamy, Ganesh Prasad, S. S. Pillai and preserve them for future historians of twentieth century mathematics in India.

Teachers of mathematics will find many interesting anecdotes which they can use to enrich the teaching of courses in calculus, theory of equations, conic sections, mechanics etc. and students will draw great inspiration from the dedication to mathematics of the mathematicians of England, Scotland and France of that period.

The book is good history, good mathematics and even good entertainment. I wish there were more such books. History of Mathematics would never be dry with such book.

Influences of Institutionalized Mathematics Teaching on the Development and Organization of Mathematical thought in the pre-modern Period

by JENS HOYRUP, Roskilde University Centre, Denmark, 1980.

Reviewed by M. S. RANGACHARI, *The Ramanujan Inst., University of Madras, Madras 600005*

The theme of the work under review is relevant to the present day context of modern development of mathematics based on the influence of certain 'schools' of mathematicians, tending to predetermine what is important or what is unimportant at any time for the further development of mathematics (e.g. Hilbert's famous lecture to the International Congress of mathematicians). The title of the work amply reveals its aim. The conclusion is that "institutionalised teaching will, so it seems, in general, *favour* the systematizing tendencies in mathematics. But it *will not always do so*, and other forces may work to the same effect."

The monograph is divided into eight sections with notes and references, bibliography and abbreviations appended at the end. After introducing the theme of the monograph in the first section, the author considers the Sumerian, Babylonian, Egyptian, Greek, Medieval Indian, Islamic, and

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Latin situations in the context of his concern before arriving at the conclusion stated above.

The author has welcomed 'critical comments' obviously because he has expected some of his assertions to be unacceptable to some students of the history of mathematics though his final conclusion may be generally accepted.

For instance, in the modern context, the influence of schools has been overrun, to a great extent, by the social and governmental pressure for applicability. The first aspect of the book which would be of too much of an inconvenience to any reader is its text-light, notes-heavy nature (which the author himself admits). For an appreciation of the theme, the notes, most often citing references and sources, need to be read along with the text so that there will be much of going forward and backward. In fact this makes the reader forget the assertions made by the author in relation to individual situations. One can cite a number of instances when the language (even the spelling, obviously because the author is alien to English Language) causes inconvenience in comprehending the author's assertion, though it could be made out contextually. The main criticism should, of course, be about the author's assertions throughout the text and notes relevant or more often irrelevant to the theme of the monograph. These assertions are not conclusions based on evidence or arguments but are either borne out of the author's unproved convictions or echo similar convictions of others. The reviewer would rather quote one or two such assertions instead of making an exhaustive list; p. 53: "During the first millenium B.C., the social classes hardened into castes . . . it was in this context of Brahmanic ritual and Brahmanic education in the sacred books that the first texts on ritual geometry (*Śulvasūtras*, presumably) were created"; p. 54: "In later times, learned commentaries were written to the treatises of ritual geometry, some of them apparently by commentators versed in Greek geometry. In the first century A.D. Greeks imported Babylonian as well as genuine Greek astronomy into India, where it was absorbed in native astronomy and brought it to a much higher level" . . . . "this conservation of style in spite of great infusions of foreign knowledge".

The author ignores historical accounts of Indian Mathematics (to cite only two, *History of Hindu Mathematics* by B. B. Datta and A. N. Singh, Asia Publishing House; *The History of Ancient Indian Mathematics* by C. N. Srinivasaienger, The World Press Private Ltd., Calcutta, 1967) preferring prejudicial writers such as Pingree, in making the latter remark, and indulges in the characteristic western abuse of the caste system in India. To say that the class system evolved by the Indian society hardened into the caste system as early as the time of the *Śulvasūtras* is too much of a political conclusion. The title "The *heirs*: India and Islam" is again mischievous in the sense that it suggests a Sumerian or Greek origin or influence

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for the Indian contribution. The implied ridicule on memorization and the cryptic form of rules (*sūtras*) reveals only the author's basic prejudice. The author forgets that this was the best form of preservation of knowledge by a community with strong memory (unlike in the west) and the memory was strengthened by the practice of the rules by skilled artisans and others. Western education in India has, unfortunately, in spite of its gains, killed this tradition.

More surprising than other convictions is the author's conviction that "the main and ever recurring element of an Indian mathematical text is the versified rule, given in a laconic and general formulation but without (with?) neither proof nor reason". The author is obviously unaware of the Malayalam work *Yuktibhāṣā* first introduced by C. M. Whish (*Trans. Roy. Asiatic Soc.*, 3, 509–523 (1835)) to the English speaking world which gives proofs of the expression as infinite series for arc tan x, sin x and cos x not influenced by Newton or Leibnitz and earlier to them (see C. T. Rajagopal and K. Mukunda Marar, *J. Bombay Branch of the Royal Asiatic Soc.*, N.S., Vol. 20 (1944), pp. 65–82; C. T. Rajagopal and A. Venkataraman, *J. Royal Asiatic Soc. of Bengal*, Science, Vol. 15 (1949), pp. 1–13). As regards the anecdote about the calendar maker of 1825 in Pondicherry the author would do well to refer to T. S. Kuppanna Sastry (*J. Madras Univ.*, Section B, Vol. 41 (1978), pp. 124–133).

The theme of the monograph is, however, an interesting one and it is upto those possessing special competence in a culture to go into the anthropology of mathematical investigation pertaining to the culture. The monograph will certainly provide an impact towards this end.

The Evolution of Dynamics: Vibration Theory from 1687 to 1742

by JOHN T. CANNON and SIGALIA DOSTROVSKY, Springer-Verlag, Berlin-Heidelberg—New York, 1981, pages ix + 184, Cloth DM 98 (Studies in Hist. of Math., Vol. 6).

Reviewed by S. D. Nigam, *I.I.T., Madras 600036.*

The book gives the salient features of the work of nine natural philosophers: Newton (1687), Taylor (1713), Sauveur (1713), Hermann (1716), Cramer (1722), Euler (1727, 35, 36, 42), Johann Bernoulli (1728, 42),

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Daniel Bernoulli (1733, 34, 39, 40, 42), Johann II Bernoulli (1736), on problems of vibration (vibrating string, sound waves, pendulum, hanging chain, vibrating rod and linked compound pendulum).

That was the era when concepts like: equations of motion, degrees of freedom, etc., were not clearly understood. The mathematical symbolism as it exists today did not exist. Even the use of calculus was highly restrictive and dominated by cumbrous but ingenious geometrical constructs. It seems surprising that the 'founding fathers' of dynamics could not write a simple equation such as

$$\rho \frac{\partial^2 y}{\partial t^2} = P \frac{\partial^2 y}{\partial z^2},$$

now known to govern the vibrations of a taut string and purely *verbal* descriptions and solutions were resorted to. It is really baffling to see that even with such imperfect tools, as they possessed at that time, they were sometimes able to obtain correct results; of course, they were men with highly developed intuition and almost an unfailing common sense!

As an example, Newton wrote as follows on pressure wave:

(1) The velocities of pulses propagated in an elastic fluid, are in a ratio compounded of the subduplicate ratio of the elastic force directly, and the subduplicate ratio of the density inversely, supposing the elastic force of the fluid to be proportional to its condensation.

(2) If the mediums be homogeneous, and the distances of the pulses [wavelengths] in those mediums be equal amongst themselves, but the motion [y] in one medium is more intense than in the other, the contractions and dilatations [strain] of the correspondent parts will be as those motions. Not that this proportion is perfectly accurate. However, if the contractions and dilatations are not exceedingly intense, the error will not be sensible; and therefore this proportion may be considered as physically exact. Now the motive elastic forces are as the contractions and dilatations; and the velocities generated in the same time in equal parts are as the forces. Therefore equal and corresponding parts of corresponding pulses will go and return together, through spaces proportional to their contractions and dilations, with velocities that are as those spaces; and therefore the pulses, which in the time of one going and returning advance forwards a space equal to their breadth, and are always succeeding into the places of the pulses that immediately go before them, will, by reason of the equality of the distances, go forward in both mediums with equal velocity.

(3) If the distances of the pulses or their lengths are greater in one medium than in another, let us suppose that the correspondent parts describe spaces [$y(z, t)$], in going and returning, each time proportional to the breadths of the pulses, then will their contractions and dilatations be

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equal. And therefore if the mediums are homogeneous, the motive elastic forces, which agitate them with a reciprocal motion, will be equal also. Now the matter to be moved [$\rho\, dz$] by these forces is as the breadth of the pulses; and the space through which they move every time they go and return, is in the same ratio. And moreover, the time of one going and returning, is in a ratio compounded of the subduplicate ratio of the matter, and the subduplicate ratio of the space; and therefore is as the space. But the pulses advance a space equal to their breadths in the times of going once and returning once, that is, they go over spaces proportional to the times; and therefore are equally swift.

(4) And therefore in mediums of equal density and elastic force, all the pulses are equally swift. Now if the density or the elastic force of the medium were augmented, then because the motive force is increased in the ratio of the elastic force, and the matter to be moved is increased in the ratio of the density; the time which is necessary for producing the same motion as before, will be increased in the subduplicate ratio of the density, and will be diminished in the subduplicate ratio of the elastic force. And therefore the velocity of the pulses will be in a ratio compounded of the subduplicate ratio of the density of the medium inversely, and the subduplicate ratio of the elastic force directly.

These verbal assertions have been translated into modern mathematical language by the authors (pp. 9–14) and it makes an interesting reading.

I found the book most exciting and I strongly recommend it to any one who wants to have a peep into the minds of 'great masters'. One is brought face to face with the birth (including labour pains) and step by step evolution of Dynamics.

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Notices of Publications

(Compiled by R. C. Gupta, Ranchi,
and A. I. Volodarsky, Moscow)

Following abbreviations are used:

AHC = *Annals of the History of Computing.*
AHRNT = *Acta Historiae Rerum Naturalium necnon Technicarum* (Praha).
GB = *Gaṇita Bhāratī.*
HM = *Historia Mathematica.*
IJHS = *Indian Journal of History of Science.*
IMI = *Istoriko-matematicheskie Issledovania* (in Russian).
JHA = *Journal for the History of Astronomy.*
JHAS = *Journal for the History of Arabic Science.*
ME = *The Mathematics Education.*
MG = *Mathematical Gazette.*
MT(I) = *Mathematics Teacher* (*India*).
RHS = *Revue d'Histoire des Sciences.*

Jesper Lützen: *The Prehistory of the Theory of Distributions*, Springer-Verlag, New York, Heidelberg and Berlin, 1982; viii + 232 pages. (N 871)

Anton Glaser: *History of Binary and Other Nondecimal Numeration*, Tomash Publishers, Los Angeles, 1981; xiv + 218 pages. (N 872)

John N. Crossley: *The Emergence of Number*, Upside Down A Book Co., Victoria (Australia), 1980; 375 pages. (N 873)

L. Radhakrishna: *History, Culture, Excitement and Relevance of Mathematics*, Shivaji Univ., Kolhapur, 1982; 80 pages (mimeographed). (N 874)

L. C. Jain: *Exact Sciences From Jaina Sources, Vol. 1: Basic Mathematics*, R.P.B. Sansthan, Jaipur, and S.B.I.S.R., New Delhi, 1982; 60 pages. (N 875)

S. D. Sharma (editor and translator): *Mānamandira Observatory of Kāśī By Bapudeva Shastri*, Martand Bhawan, Kurali (Punjab), 1982; xxiv + 50 pages, 1 plate (original work in Sanskrit). (N 876)

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A. M. HEINEN: *Islamic Cosmology: A Study of as-Suyūṭī's al-Hay'a as-sanīya fī l-hay'a as-sunnīya* (with critical edition, translation, and commentary), Beirut, 1982; (Beiruter Texte und Studien, Band 27); viii + 289 + 80 pages. (N 877)

A. DJAFARI NAINI: *Geschichte der Zahlen-theorie im Orient*, Verlag Klose & Co., Braunschweig, 1982; 223 pages. (N 878)

JÖRAN FRIBERG: *A Survey of Publications on Sumero-Akkadian Mathematics, Metrology and Related Matters (1854–1982)*, Chalmers Univ. of Technology and Univ. of Göteborg, Göteberg (Sweden), 1982; xv + 155 pages (mimeographed). (N 879)

B. B. HUGHES (editor and translator): *Jordanus de Nemore, De Numeris Datis*, Univ. of California Press, Berkeley and Los Angeles, 1981/1982; xii + 212 pages. (N 880)

J. N. CROSSLEY (editor): *First Australian Conference on History of Mathematics* (Proceedings of a Conference at Monash Univ., 1980), Dept. of Math., Monash Univ., Clayton, 1981; v + 199 pages. This has items *N 882* to *N 895* below. (N 881)

———: "Opening Remarks", pp. 1–4 in *N 881*. (N 882)

R. A. BRYCE: "Ruffini and the quintic equation", pp. 5–31 in *N 881*. (N 883)

M. A. B. DEAKIN: "A Scandal in Vienna", pp. 32–40 in *N 881*. (N 884)

D. FEARNLEY-SANDER: "Hermann Grassmann and the Prehistory of Universal Algebra", pp. 41–51 in *N 881*. (N 885)

———: "Grassmann's Theory of Dimensions", pp. 52–82 in *N 881*. (N 886)

R. J. GILLINGS: "On the Presentation of Early Mathematics", pp. 83–90 in in *N 881*. (N 887)

HO PENG-YOKE: "Ancient Chinese Mathematics", pp. 91–102 in *N 881*. (N 888)

JOCK HOE: "Zhu Shijie and his *Jade Mirror of the Four Unknowns*", pp. 103–134 in *N 881*. (N 889)

K. HUTCHISON: "Euler, Dollond, Klingenstierna and the refutation of Newton's stance on chromatic aberration", pp. 135–144 in *N 881*. (N 890)

ST. J. KETTLE: "The early life of Moebius, and the world in which he lived it", pp. 145–158 in *N 881*. (N 891)

J. D. MACKENZIE: "Dialogue and Proof", pp. 159–167 in *N 881*. (N 892)

E. SENETA: "Least Squares in Pre-Revolutionary Russia", pp. 168–174 in *N 881*. (N 893)

G. C. SMITH: "Boole's Annotations on the 'Mathematical Analysis of Logic'," pp. 175–179 in *N 881*. (N 894)

G. J. TEE: "Two New Zealand Mathematicians", pp. 180–199 in *N 881*. (N 895)

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PARMESHWAR JHA: "Āryabhaṭa I and the Value of π", *ME*, **16** (1982), Sec. A, 54–59. (N 896)

S. A. PARAMHANS: "Some Mathematical Facts in Indian Scriptures", *Ibid.*, Sec. B, 37–40. (N 897)

R. S. LAL: "Squaring in Ancient Hindu Mathematics", *ME*, **16** (1982), Sec. A, 91–97. (N 898)

G. S. JHA: "Mathematics in Literature", *Ibid.*, Sec. B, 52–62. (N 899)

Y. C. ASHAKIRAN: "On the construction of singly magic squares of order 4", *Ibid.*, Sec. B, 63–64. (N 900)

LEO SAUVE: "The Steiner-Lehmus Theorem", *MT(I)*, **16** (1980), 32–36. (N 901)

R. NARASIMHAN: "The Fields Medal", *Ibid.*, 42–44. (N 902)

VENKATESHMURTHY: "An explanation to the (short cut) method of Bhāskara II to solve indeterminate equations of the first degree", *MT(I)*, **17** (1981), 25–29. (N 903)

G. SAMA RAO: "A Problem of Ancient India Solved", *Ibid.*, 30–38. (N 904)

ANONYMOUS: "Some results in Mathematics which I find interesting", *Ibid.*, 44–47. (N 905)

S. DAS: "Computational Algorithms and Vedic Mathematics", *Society and Science* (Bombay), **3**(1) (1980), 21–37. (N 906)

D. SAH AND G. S. JHA: "Indian Concept of Gravitation", *The Indian Nation* (Patna), 17 January, 1982. (N 907)

S. E. BRODIE: "Archimedes' Axioms for Arc-length and Area", *Math. Magazine*, **53** (1980), 36–39. (N 908)

M. J. COLLISON: "The Unique Factorization Theorem from Euclid to Gauss", *Ibid.*, 96–100. (N 909)

J. LÜTZEN: "Joseph Liouville's Contribution to the Theory of Integrals Equations", *HM*, **9** (1982), 373–391. (N 910)

H. M. PYCIOR: "Early Criticism of the Symbolical Approach to Algebra", *Ibid.*, 392–412. (N 911)

ERHARD SCHOLZ: "Herbart's Influence on Bernhard Riemann", *HM*, **9** (1982), 413–440. (N 912)

GERT SCHUBRING: "Ansätz zur Begründung theoretischer Terme in der Mathematik—die Theorie des Unendlichen bei Johann Schultz", *Ibid.*, 441–484. (N 913)

G. H. MOORE: Review of *A Half Century of Polish Mathematics: Remembrances and Reflections* (by K. Kuratowski, 1980) and *Waclaw Sierpienski: Oeuvres Choisies* (ed. by S. Hartman *et al*, 3 vols, Warsaw, 1974–1976), *Ibid.*, 489–495. (N 914)

H. KENNEDY: Review of *Matematica: Un Profilo Storico* (by D. J. Struik, Bologna, 1981), *Ibid.*, 495–496. (N 915)

E. G. FORBES: "The European astronomical tradition: its transmission into India, and its reception by Sawai Jai Singh II", *IJHS*, **17** (1982), 234–243. (N 916)

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M. L. SHARMA: "Jagannath Samrat's Outstanding Contribution to Indian Astronomy in Eighteenth Century A.D.", *Ibid.*, 244–251. (N 917)

A. K. MEHRA: "Solar Eclipse Theory and Observations in the 18th Century India", *Ibid*, 252–259. (N 918)

V. N. SHARMA: "Jai Singh, his European astronomers and the Copernican revolution", *Ibid.*, 333–344. (N 919)

V. N. SHARMA: "The impact of the eighteenth century Jesuit astronomers on the astronomy of India and China", *IJHS*, **17** (1982), 345–352. (N 920)

A. R. VERMA: Review of *Studies on Christiaan Huygens* (ed. by H. M. Bos, *et al*, 1980). *Ibid.*, 394–395. (N 921)

K. A. RYBNIKOV: "On the variety of mathematical knowledge" (in Russian), *The History and Methodology of Natural Sciences* (in Russian), **29** (1982), 3–8. (N 922)

I. G. BASHMAKOVA and L. E. MAISTROV: "On the first course on history of mathematics in Moscow University" (in Russian), *Ibid.*, 9–30. (N 923)

E. I. BEREZKINA: "On the mathematical methods in the ancient time (from the history of the system of notation)" (in Russian), *Ibid.*, 31–41. (N 924)

L. G. BIRYUKOVA: "*Die Grösenlehre* by Robert Grassmann and constructive approach in the mathematics of 19th century" (in Russian), *Ibid.*, 41–50. (N 925)

S. S. GLUSHKOV: "Algebraic approach to geometric problems as the source of De Moivre's formula" (in Russian), *Ibid.*, 51–56. (N 926)

F. R. GLUSHKOVA AND S. S. GLUSHKOV: "On the geometrical part of Pacioli's *Summa*" (in Russian), *Ibid.*, 57–63. (N 927)

A. V. DOROFEEVA: "The calculus of variation in the last third of the 19th century" (in Russian), *Ibid.*, 64–74. (N 928)

Z. A. KUZICHEVA: "The graphic methods of classes' logic" (in Russian), *Ibid.*, 75–85. (N 929)

F. A. MEDVEDEV: "On the two proofs of the theorem of finite covering" (in Russian), *Ibid.*, 86–90. (N 930)

S. S. PETROVA: "G. Boole and the development of the calculus of operations in England" (in Russian), *Ibid.*, 98–103. (N 931)

N. G. HAIRETDINOVA: "The theory of Regiomontanus ratio" (in Russian), *Ibid.*, 104–106. (N 932)

L. A. SOROKINA: "On the works of Minding devoted to the theory of Abelian Integrals" (in Russian), *Ibid.*, 144–151. (N 933)

A. V. TEPLITSKAYA: "A reflection on the work of mathematicians in the book series 'The prominent scientists of the Moscow University' " (in Russian), *Ibid.*, 166–172. (N 934)

J. FRIBERG: "Methods and Traditions of Babylonian Mathematics, II: An Old Babylonian Catalogue Text with Equations for Squares and

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Circles", *Journal of Cuneiform Studies*, **33** (1981), 57–64. (N 935)

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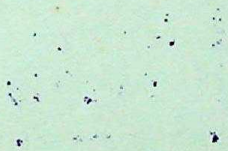

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